Short-Range Proximity Effect Correction for EUV Mask Writing

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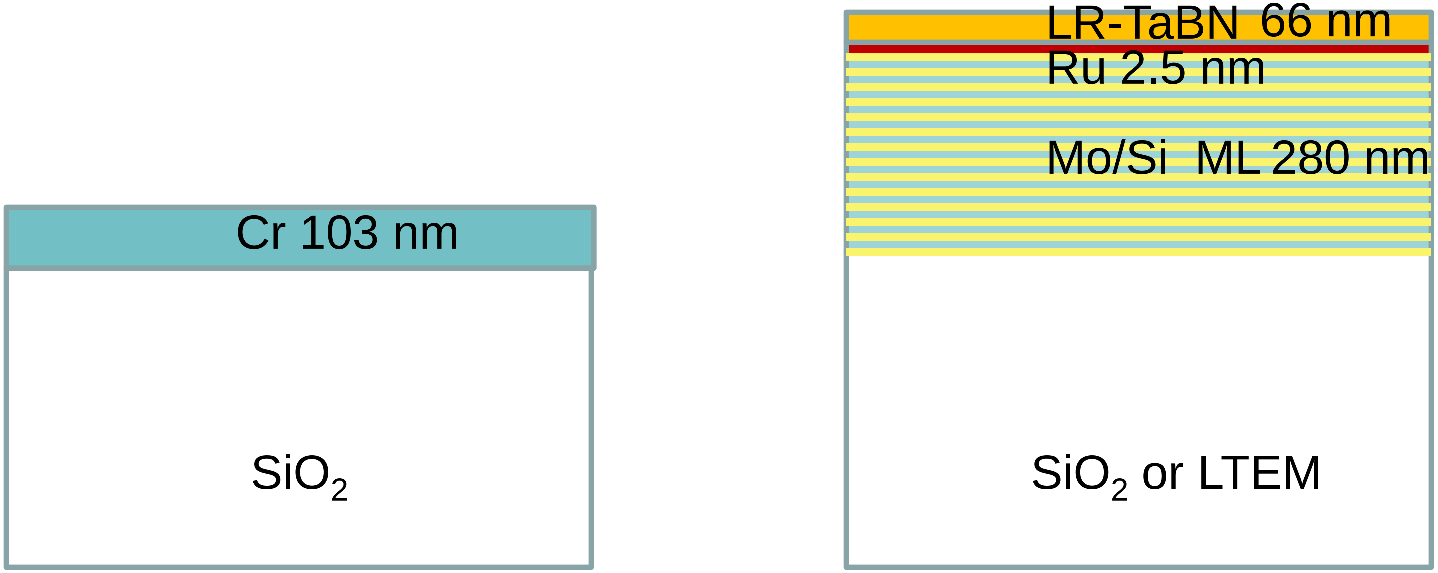
Introduction

Photomask

EUV mask

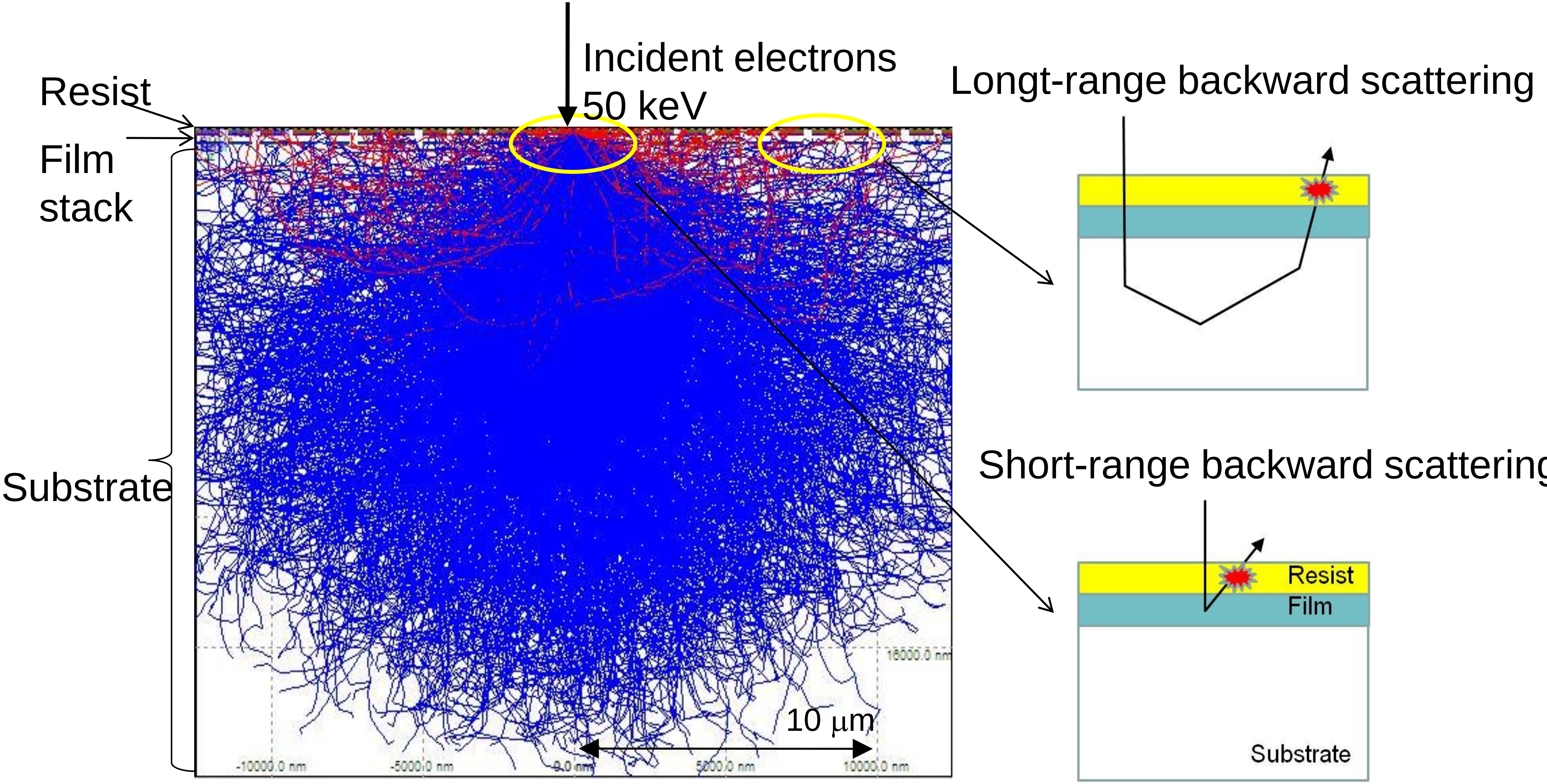


EUV mask film stack is much thicker than photomask film stack
Heavier metals (Ta, Mo) scatter more electrons

DNP

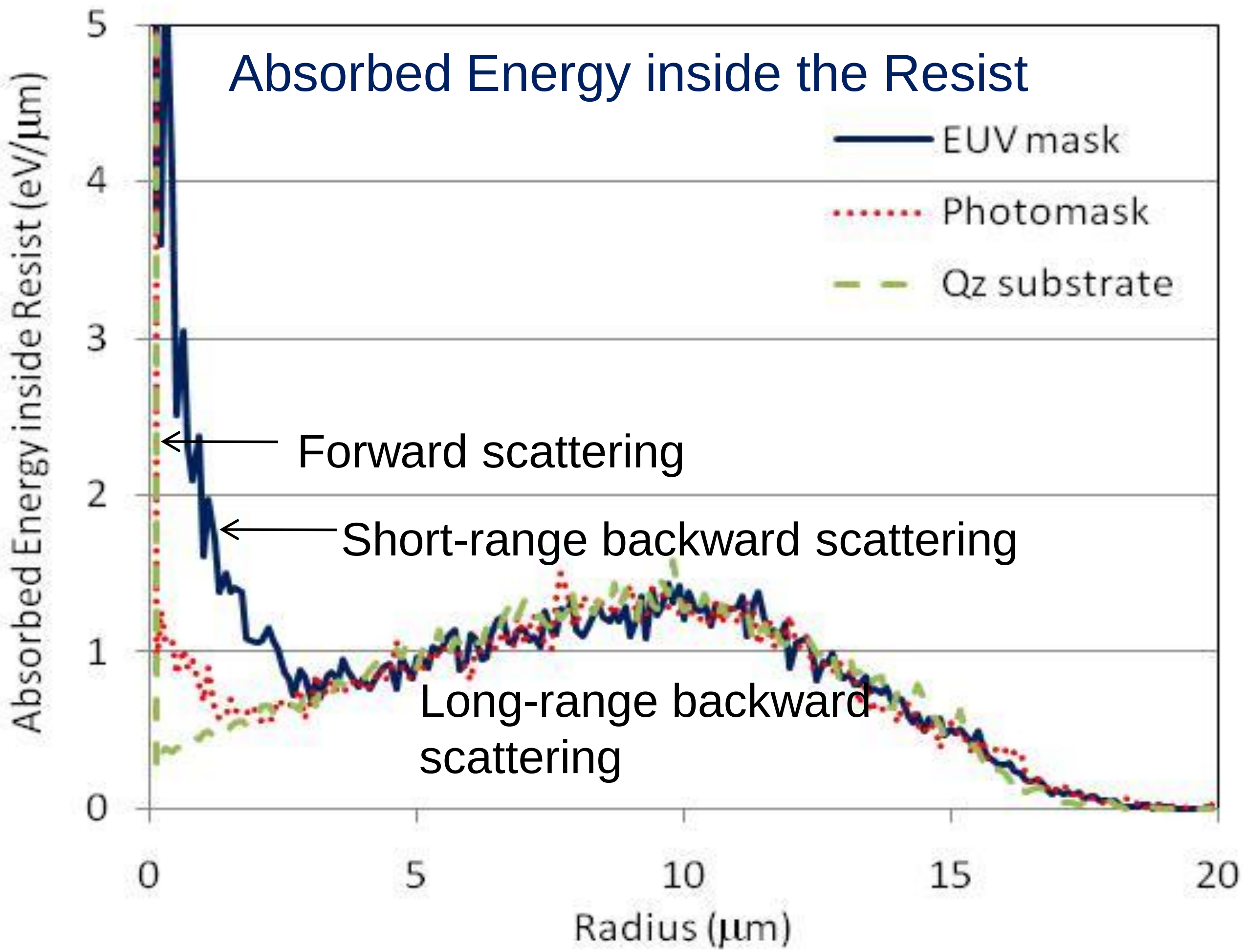
intel

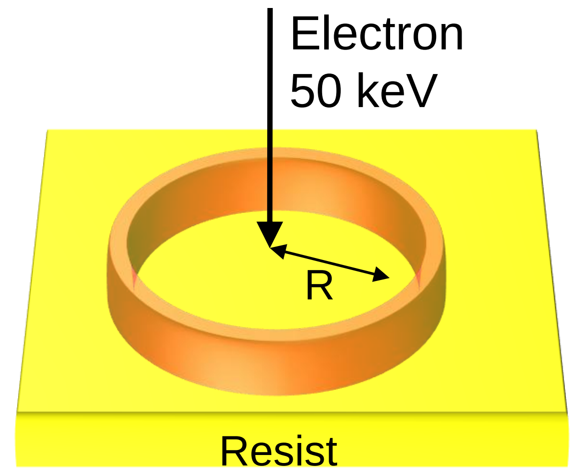
Monte Carlo Simulation (1)



Red curves are backward scattered electrons

Monte Carlo Simulation (2)





Absorbed energies by short-range backward scattering is ~25% of the energies by long-range backward scattering

Proximity Effect Correction Methods

1. Dose modulation during EB writing
   - Conventional method
   - Calculation grid size is limited by hardware

2. Mask biasing
   - EB writer friendly ([1] Kamikubo et al., BACUS 2010)
   - Difficult to separate backscattering from etch/dev loadings

3. Dose assignment before EB writing
   - Known as shot-rank method
   - Very short-range forward scattering can be incorporated ([2] Tsunoda et al., BACUS 2010)

We select the shot-rank method in this paper

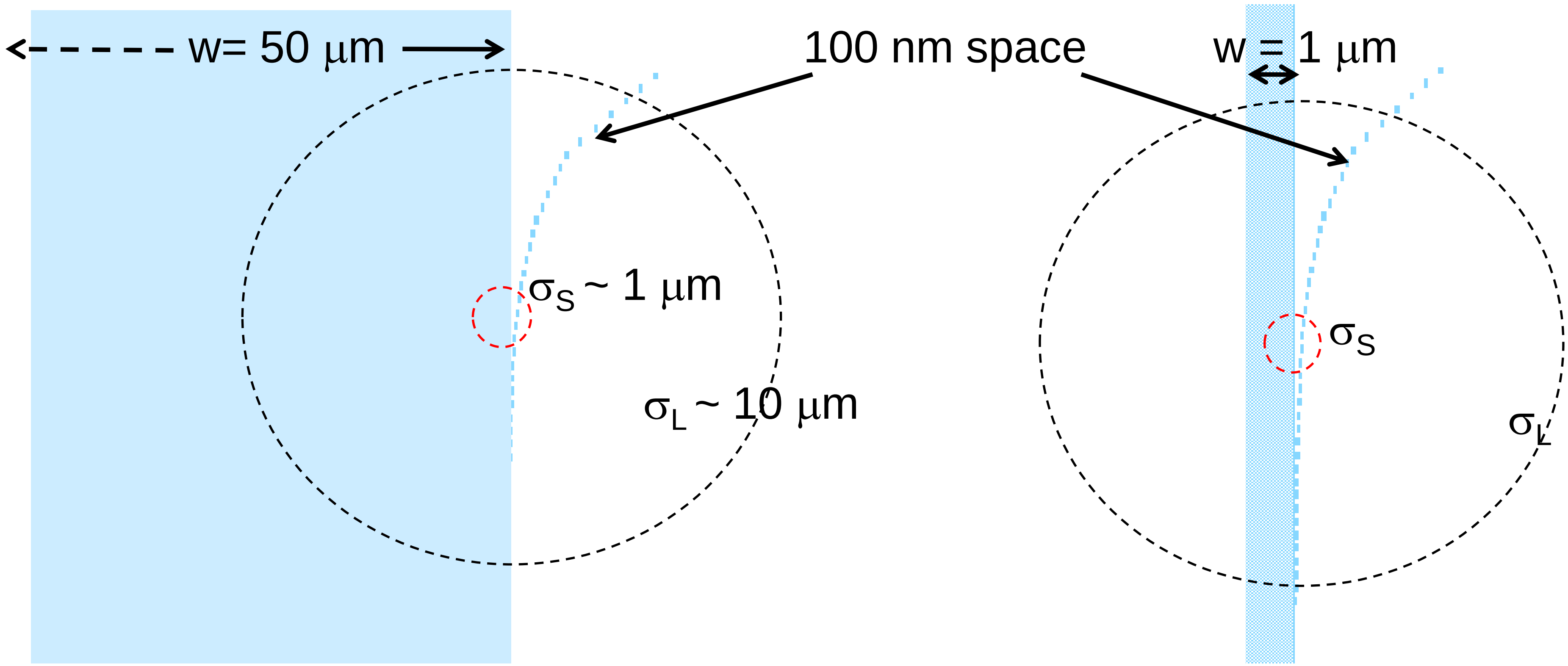
Experimental Setup

- Substrate: Qz
- Film structure: Shown in P. 2
- Resist: Posi CAR
- EB writer: 50 keV VSB
- Etcher: ICP-RIE

- PEC software: Ref. [2]
- Number of shot ranks: 64
- PEC parameters:

  Forward scattering range σ_F: 30 nm, fixed
  Long backscattering range σ_L: variable
  Long backscattering strength η_L: variable
  Short backscattering range σ_S: variable
  Short backscattering strength η_S: variable

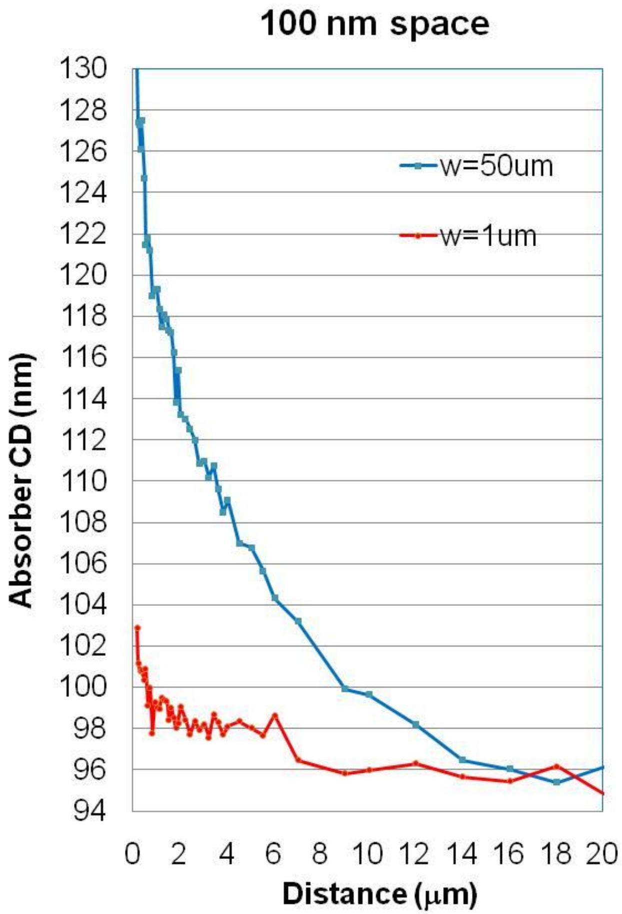
Proximity Test Pattern



- We measured the CDs of 100 nm space adjacent to the w= 50 μm and 1 μm area
- Influence of the long-range backscattering is small when w=1 μm

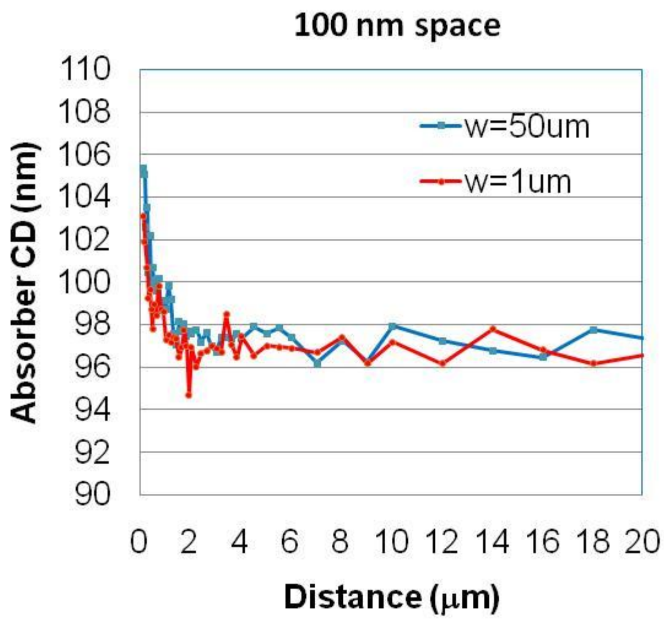
Proximity Effect

No PEC



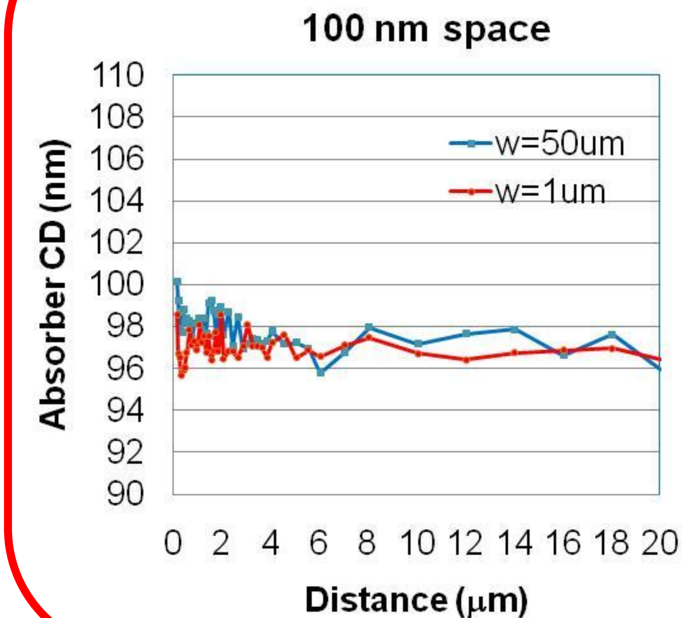
σ_L 10 μm η_L 0.35

Long-range PEC only



σ_L 10 μm η_L 0.35

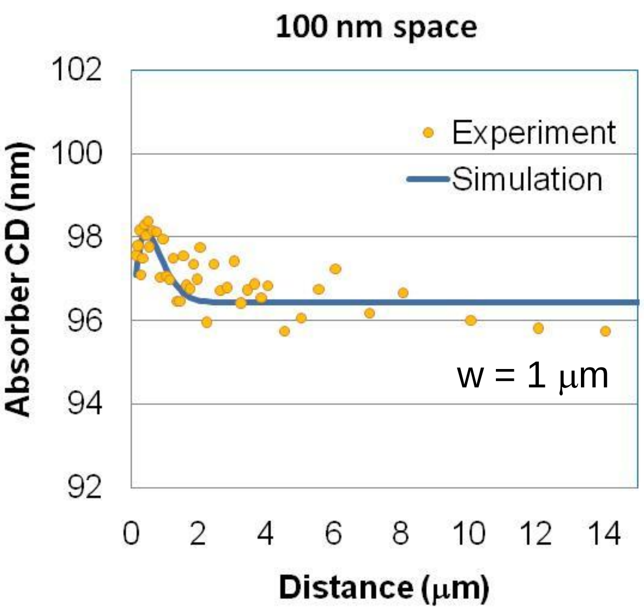
σ_S 0.9 μm η_S 0.1



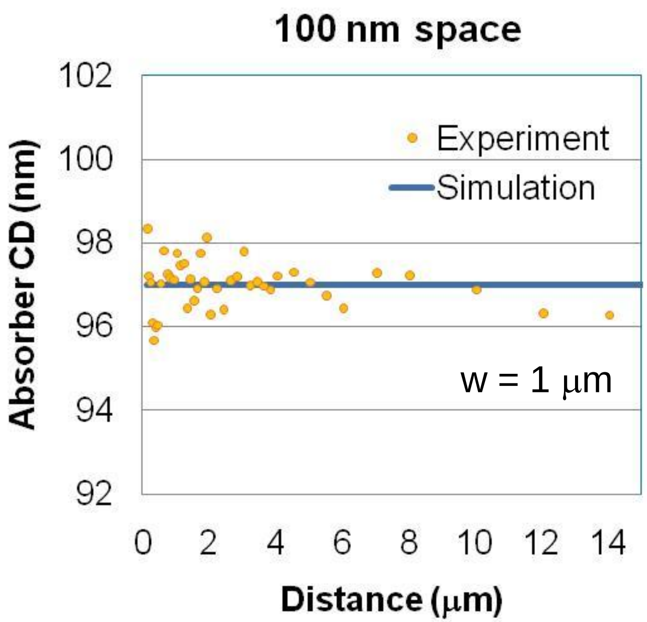
Both long-range and short-range backscattering effects were successfully corrected

Short Backscattering Range

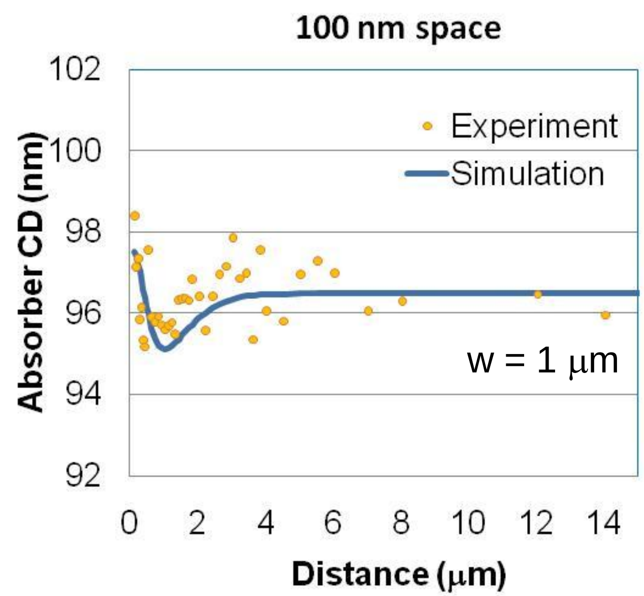
σ_L 10 μm η_L 0.35
σ_S 0.45 μm η_S 0.1



σ_L 10 μm η_L 0.35
σ_S 0.9 μm η_S 0.1

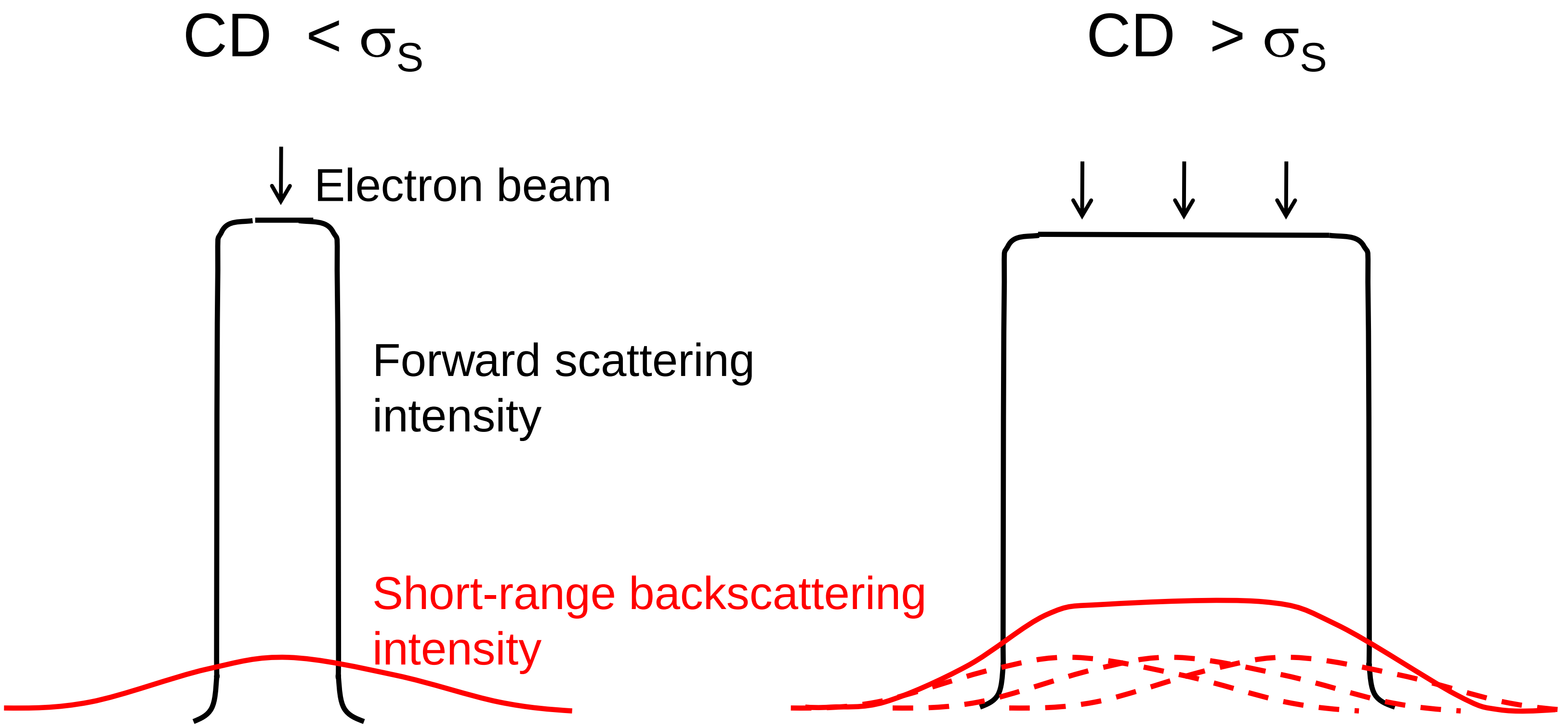


σ_L 10 μm η_L 0.35
σ_S 1.8 μm η_S 0.1



- Simulation (threshold model) assumes σ_S=0.9 μm
- Experimental data and simulation results are well matched. The range of short backscattering is ~ 1 μm.

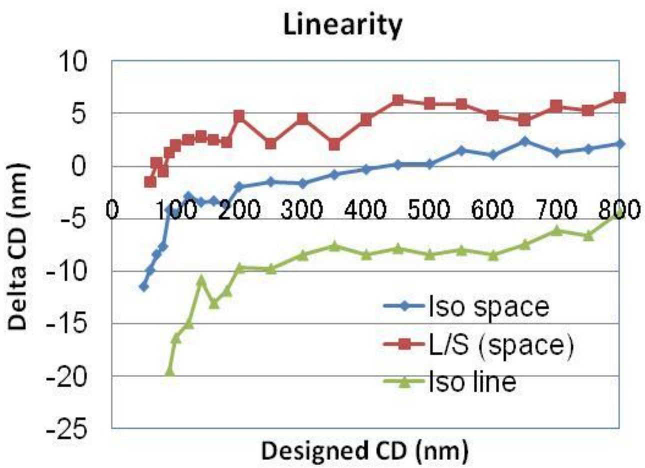
Short-range Backscattering Effect on Linearity



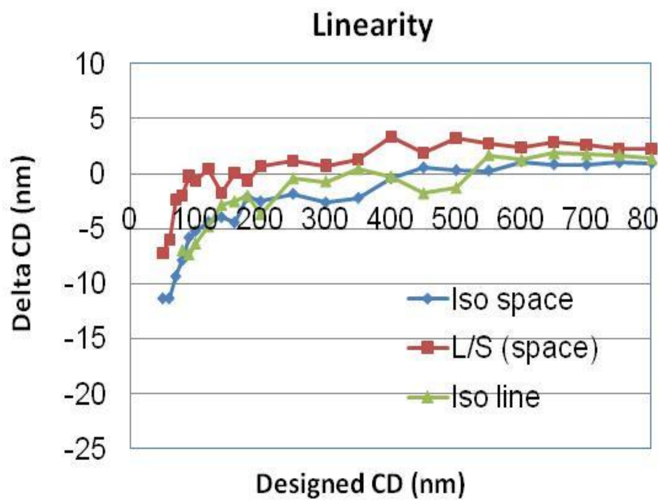
Short-range backscattering intensity depends on CD

Linearity

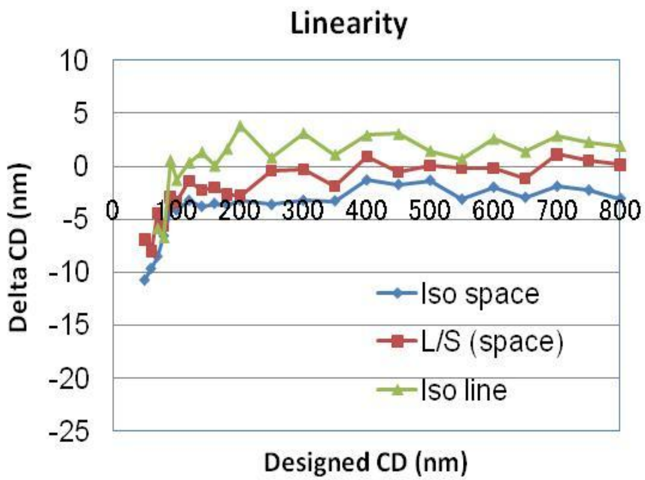
σ_L 10 μm η_L 0.35
Long-range PEC only



σ_L 10 μm η_L 0.4
Long-range PEC only



σ_L 10 μm η_L 0.35
σ_S 0.9 μm η_S 0.1



Linearity becomes better by including short-range PEC

Summary

- Short-range electron backscattering causes large effects on EUV mask CD shift
- Shot-rank method was used for the proximity effect correction of short-range backscattering
- Proximity effects were successfully corrected by including the short-range PEC
- The range of the short-range backscattering is ~ 1μm
- Short-range backscattering affects to the mask linearity. It was improved by including the short-range PEC.